BBSRC NIBB AD Network
All Business Interaction Vouchers: FINAL REPORTS

2014 BIV Final Reports

BIV2014001
Permastore/Dr Sonia Heaven **Testing of anaerobic digester components found in thermophilic digestion of food wastes**
Permastore is the world's leading manufacturer of Glass-Fused-to-Steel tanks and silos, with more than 300,000 structures installed worldwide in over 110 countries. The wide range of applications already includes anaerobic digestion and biogas and biofuels production. The company's aim is to remain at the forefront of development in this field, and to ensure its continuing ability to provide customers with optimum solutions for their containment requirements, and with secure, long-life systems for an expanding range of applications in both anaerobic digestion and novel anaerobic biotechnologies. The company therefore wished, in association with the Bioenergy and Organic Resources Research Group at the University of Southampton, to develop a testing protocol that would allow materials destined for potential use in advanced applications to be validated. This would include operation at thermophilic temperatures and where harsh conditions are likely to arise in digesters, both in normal operation and where the process becomes unstable or fails. The testing procedure developed was based on continuous simulation of the digestion process in small pilot-scale anaerobic digesters, and has provided comprehensive data that would not be available from simple batch tests. Trials on samples provided by Permastore Ltd were successfully carried out using source separated domestic food waste obtained from commercial collections operated by UK waste management contractors: this material is itself an interesting and challenging feedstock under thermophilic conditions because it generates high concentrations of ammonia in the digestate, which can be toxic to the microbial consortium that carry out the process. An innovative side-stream stripping process was therefore used to ensure stable operation in the thermophilic temperature range used, and provide a controlled range of test conditions for the trials. The project allowed the partners to draw on their combined expertise to develop and apply an appropriate in-vivo material testing regime, and to work together on evaluating the results from trials carried out over a period of six months. In addition to providing robust test results, the project has also led to publishable data on the successful operation of ammonia stripping and the performance of thermophilic digestion of food waste in these conditions. Further trials have been commissioned using the same approach and, and the scientific data on digester operation will be disseminated through journal publication.
Researchers: Dr Sonia Heaven University of Southampton

BIV2014002

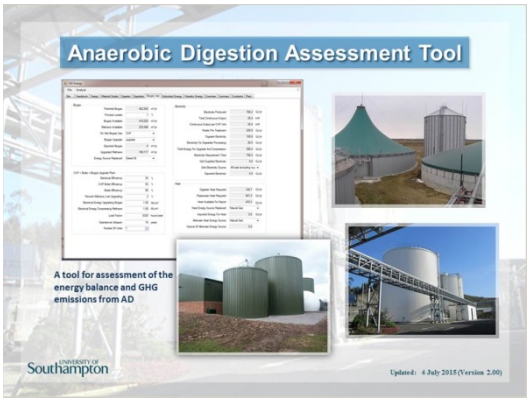
IEA Task 37/Dr Sonia Heaven

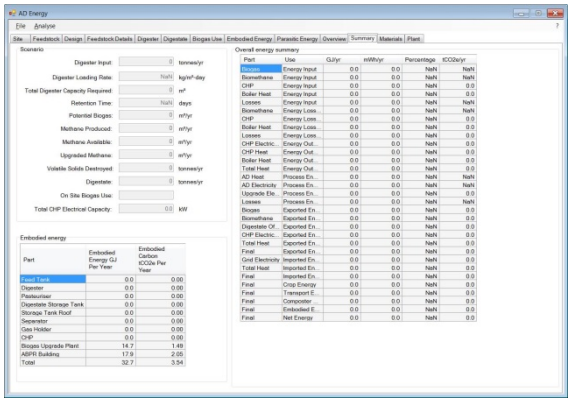
A modelling tool for the UK AD industry

Rapid expansion in the UK anaerobic digestion (AD) sector has created a need for powerful, flexible and readily-accessible modelling tools for the outline design, benchmarking and assessment of AD facilities. The current project took an existing model on which extensive development work has already been carried out, and completed the task of re-configuring it into a user-friendly software package suited to the needs of a wide range of end-users.

An AD modelling tool was first developed as part of the EU FP7 CROPGEN project (www.cropgen.soton.ac.uk) for analysis of agricultural biogas energy systems, and included databases on crop production systems and their direct and indirect energy and nutrient requirements. These were extended with specific data for UK agricultural systems as part of the RCUK RELU programme (www.ad4rd.soton.ac.uk). A version of the model was adapted to accommodate commercial and municipal waste as part of the FP7 VALORGAS project (www.valorgas.soton.ac.uk). It is thus one of the most extensive and rigorously tested modelling tools of its type currently available in Europe. Its major limitation before the current project was that some aspects still relied on the use of Excel spreadsheets, reducing uptake and limiting its adoption to those familiar with this type of application. The current work has re-combined key aspects of the different versions into a software package based on a high-level programming language, and has tailored inputs and outputs to meet the needs of industry and agricultural in the UK. The resulting tool allows prediction of detailed energy and nutrient balances for AD plants, which are also expressed in terms of the greenhouse gas emissions associated with the process.

The combined expertise of IEA Task 37 (UK) and the academic partners was used to develop and test a new user interface suitable for industrial and farm-based applications at a range of scales. This was achieved through close collaboration between industry and academic members of Task 37, who offered their time and expertise as in-kind contributions to achieve the desired goal. The software will be made freely available for download from the website of the Bioenergy and Organic Resources Research Group (www.bioenergy.soton.ac.uk) at the University of Southampton. The modelling tool can be used by industry users and researchers, promoting a common framework for evaluation of new and existing AD plants, and increased collaboration across the UK AD community.





Screenshots of opening screen and summary tab for Anaerobic Digestion Assessment Tool

Researchers:
Dr Sonia Heaven
University of Southampton

2015 BIV Final Reports

BIV2015002
Lutra Ltd/Dr David Styles **Providing a scientific evidence base for public subsidy support of biomethane for transport from waste**
The environmental balance of the Barret's Mill Anaerobic Digestion (BMAD) system to generate biomethane for transport (BfT) from food waste was evaluated using an adapted version of Bangor University's LCAD Eco Screen tool. Scenarios were run for a commercial variant of the BMAD system capable of processing 750 t/y household foodwaste plus 250 t/y of commercial (pubs, restaurants, etc.) food waste, at 30% dry matter (DM) and with biomethane yields of 440 m3/t DM and 450 m3/t DM, respectively. The scenarios assumed that BMAD systems would be deployed to serve the 11.5 million people living in settlements of 5000 – 25,000 people (too small for large-scale AD units). It was assumed that household waste would otherwise have gone to composting, and that commercial waste would otherwise have gone to landfill. Around 300,000 tonnes of CO2e could be saved annually from the deployment of the BMAD system in the UK, avoiding almost 1.9 PJe of fossil energy. Emissions of eutrophying substances would be slightly reduced, but an increase of 224 t SO2e/yr of acidifying emissions, primarily in the form of NH3, could have negative consequences for air quality. Avoided diesel combustion and avoided waste management emissions contribute almost equally to CO2e avoidance, whilst avoided waste management dominates the eutrophication credits. There is some uncertainty about the magnitude of environmental credits (avoided burdens) associated with counterfactual waste management. Despite large fossil resource savings for the national scenario, significant quantities of electricity are required from the grid to supply the digester and upgrade plant. This significantly reduces the overall fossil energy substitution of the BMAD system, but could be mitigated through the use of on-site renewable energy sources, such as solar PV panels, to provide a portion of the electricity requirements. BfT also significantly reduces NOx and particulate matter emissions to air compared with substituted diesel combustion. Approximately £5.5 M/yr of damages from NOx and PM emissions could be avoided through the substitution of diesel with BfT if BMAD systems were widely deployed at the national level. If the CO2e damage costs are also taken into account, considering a range of values between £10 and £50 per tonne of CO2e, then BMAD national deployment could lead to additional savings of between £3 M and £15 M per year. The BMAD system appears to represent an environmentally-sustainable solution to the problem of organic waste management for small towns and rural areas that don't generate enough waste to support more typical large-scale anaerobic digestion plants. Through the avoidance of in-vessel composting and landfilling, the BMAD system can generate transport fuel with a negative carbon footprint, even after electricity requirements for BfT upgrade are accounted for. BfT could be used to power local buses more cleanly than diesel, also reducing local air pollution.
Researchers: Dr David Styles Bangor University

BIV2015003

Renewable Energy Association / Dr David Styles

Evaluating cost-effective greenhouse gas abatement by small-scale anaerobic digestion

This project focused on the benefits of small scale AD largely based on manures/slurries, with particular focus on GHG emission abatement potential and cost effectiveness in abating CO2e emissions when compared with other options. The Bangor University LCAD Eco Screen tool was used to calculate the net GHG emission abatement achieved by one tonne dry matter slurry throughput, considering a range of counterfactual (avoided) manure storage systems (lagoon, open tank, closed/crusted tank). These data were extrapolated up to national scenarios using statistics on farm size and manure management practices.

On-farm AD has significant potential to capture, as a renewable energy source, GHG emissions (e.g. methane) that would be otherwise released by storage and handling of manures and slurries. This means that there are significant GHG savings resulting from anaerobic digestion of manures/slurries due to avoided methane emissions from conventional manure/slurry storage and spreading. Use of methane from manures/slurries (on their own or in combination with crop feedstocks and residues) not only removes a direct source of GHG emissions, but also displaces the use of fossil fuels in terms of energy production also fertiliser manufacture (enhanced fertiliser-replacement value of digestate compared with slurry), thus further reducing net GHG emissions.

Small scale, farm AD largely based on manures/slurries is typically less cost-effective in cost per kWh generated than larger scale electricity generation. However, results of this study demonstrate that, owing to the large GHG abatement from avoided manure/slurry storage, it is much cheaper when looking at it in terms of carbon savings. Results show that each tonne of dry matter of cattle slurry avoids 1449 kg CO2e, and generates 443 kWh of electricity, leading to a GHG abatement cost of £60 per tonne of CO2e saved at a FIT rate of £0.20 per kWh. This compares very favourably with £182 per tonne of CO2e, which is the cost estimated for other renewable electricity generation based on a subsidy level of £0.09 per kWh (previously taken by Government as the maximum level it should pay for renewable energy). Thus, we conclude that even at a FIT rate of £0.20 per kWh, small scale farm AD largely based on manures/slurries would represent cost-effective GHG abatement.

This project showed that GHG savings as high as 1.8 million tonnes of CO2e per year could be achieved in the UK if AD were to be deployed across all dairy farms with more than 133 milking cows. Deploying AD on large dairy farms only would still potentially avoid over 600,000 tonnes of CO2e per year. In summary, GHG savings would be considerable and could significantly contribute to meet UK Carbon Budgets.

In conclusion, small scale, on-farm AD largely based on manures/slurries can play a significant role in GHG abatement in the future and can deliver this cost effectively. However, the current FIT regime is inadequate to support an increase in the uptake of smaller scale AD projects and should therefore be revised to recognise the potential of on farm AD to achieve cost effective carbon reductions and combat climate change.

Researchers:
Dr David Styles,
Bangor University

BIV2015007

William Jackson Food Group/Dr Davide Dionisi
Anaerobic digestion of vegetable waste from the food industry

This study has investigated the anaerobic digestion of vegetable waste provided by the industrial partner in a range of operating conditions.
The VW sample was homogenised using a food processor/liquidiser. The sample was stored in a freezer at -18°C and defrosted before being fed into the reactor. Total and volatile suspended solids (TSS: 21.4 g/L, VSS: 21.3 g/L), chemical oxygen demand (COD: 62.9 gCOD/L) were measured according to standard methods. The initial pH of the substrate was 4.6. The reactors were inoculated with sludge from an existing anaerobic digester. The feed was maintained at 4°C to prevent bacterial metabolic activity and the experiments were carried out at 35°C. The process was monitored by periodic sampling for the analysis of the COD, VSS, total and soluble carbohydrates, pH, ethanol and VFA.
Four experimental runs were carried out in this project:
Run 1: continuous reactor at HRT of 10 days;
Run 2: continuous reactor at HRT of 20 days;
Run 3: continuous reactor at HRT of 20 days with addition of sodium bicarbonate to the feed;
Run 4: batch reactor.

The main results obtained can be summarised as follows:
- In all the investigated conditions the main process occurring was the conversion of the organic matter to volatile fatty acids (VFAs). Indeed, the total COD of the liquid phase in the reactor was in all cases at least 80% of the total COD of the feed, indicating low conversion to gas products. The low conversion to gas products is explained with the low pH of the feed, which inhibits methanogenesis. The average pH of the reactor varied from 5 (Run 1) to 6.5 (Run 3). The higher pH in Run 3 was due to the addition of sodium bicarbonate to the feed, however this was not enough to stimulate methanogenesis;
- In the continuous runs, degradation of the carbohydrates in the feed was in the range 50-80%, the highest values obtained for Run 3, the lowest values for Run 1. Degradation of the VSS in the feed was in the range 15-40%, the highest values being observed for Run 3.
- In the continuous runs, the VFA production yield was in the range 23-35% (on a COD basis) the highest value being observed for Run 3 and the lowest value for Run 1. The total concentration of VFAs was in the range 10-20 g COD/l, with the highest values observed for Run 3;
- Acetic acid, propionic acid, butyric acid and caproic (hexanoic) acid were the main fermentation products. Caproic acid was only detected in Runs 2 and 3. Acetic acid was usually the most abundant VFA produced. The concentration of butyric acid and caproic acid increased with increasing HRT. Ethanol, up to 1 g/L, was detected at the investigated conditions;
- In the batch run, the yield of products in the liquid phase increased with time, as expected. The final yield was approximately 40%, on a COD basis, and the main products were acetic and butyric acids.
In conclusion, this study shows that, for the vegetable waste considered in this study, the conversion to VFAs is feasible under a wide range of operating conditions. The conversion to methane is more problematic, probably due to the acidic pH of the waste.

"The issue of food waste has a continuing high profile and understanding how best to address individual waste streams is a key concern across the agri-food sector. To succeed in the aim of 'doing more with less' requires detailed understanding of the various options available for any given waste stream, prioritising those which are genuinely unavoidable. In this project we have deliberately focused on such material and have gained a very useful insight into an alternative route beyond the more-established methanogenic AD and animal feed. We are confident that

significant commercial opportunities may arise from continued investigation and hope to collaborate further with Aberdeen University and other academic institutions where we have pursued allied work." Dr Gavin Milligan - William Jackson Food Group
Researchers: Dr Davide Dionisi, University of Aberdeen

2016 BIV Final Reports

BIV2016003
BIV2016003 - Tropical Power Ltd./Prof. Charles Banks Process optimisation of Africa's first commercial grid connected AD plant

Tropical Power is an engineering procurement and construction company building renewable energy solutions for Africa: its focus is on developing utility-scale sustainable energy technologies including anaerobic digestion (AD) and photovoltaics. The Company plans to build renewable power assets producing over 130 MW of clean, distributed power. The first of these was commissioned as Africa's first commercial grid-connected AD plant in 2016. It is situated at Gorge Farm Energy Park in Nakuru County, Kenya and is currently fed on maize stover from baby sweetcorn and trimmings from other high-value vegetables grown for export, mainly to the UK; future feedstocks may also include drought-tolerant plants from non-irrigated marginal lands that cannot be used for food production.

Because this type of mixed feedstock has not previously been used elsewhere, there was scope for optimising the plant's performance in terms of its energy use and overall efficiency. To achieve this, the University of Southampton (UoS) has been working with the Company to set up a testing and monitoring laboratory, train staff, and advise on plant operation. This involved spending 3 weeks on site at the Gorge Farm energy park to assess the facilities, and make recommendations on how these could be improved to allow a flexible approach to evaluation of plant performance through testing of feedstock methane potential, monitoring plant stability, and improving feedstock conversion rates.

During the visit Prof Banks had discussions with all members of the plant operational and management staff to decide which the key parameters to monitor were, which could be done continuously, which required additional laboratory facilities and staff training, which should be carried out in Kenya, and which required shipment of samples to external analytical laboratories. As a result the Company invested in some additional equipment which gave a much greater 'in house' potential; and the training and advice provided gave locally-employed staff the ability and confidence to provide the operational team with day-to-day data on the stability of the plant.

Further feedstock samples were taken for analysis to assess any nutrient deficiencies, and as a result a bespoke trace element cocktail has now been supplied to Tropical Power by a UK company.

Training was also given on how to establish the methane potential of different feedstock types, and the Company has now invested in equipment to give the laboratory in Naivasha the capability of testing a range of indigenous drought-tolerant species that are non-competitive with food crops and could be used as future energy substrates. This part of the work is now continuing with UoS working with Tropical Power on a FCO Prosperity Fund grant.

The BIV also allowed the Company to work with the University partners to identify those parameters that can affect the sustainability of the project, and baseline data has been collected which will be used in modelling of the results to provide further guidance on plant optimisation and improving its environmental performance.

Mike Mason, Chairman of Tropical Power said *"The interaction with Southampton University has helped us overcome many of the technical difficulties associated with the commissioning of a new plant, using a new feedstock, in a country with no other industrial-scale digesters to provide inoculum. It is excellent that we now have a full technical capability in our laboratory. The staff benefitted hugely from the training provided, and this is allowing us to explore the possibility of using new substrates and innovative harvesting and pre-treatment methods".*

Researchers:
Prof. Charles Banks
University of Southampton